

Characterizing Droplet Formation from Non-Linear Slosh in a Propellant Tank

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Abstract:

The Fluid Dynamics Branch (ER42) at the Marshall Space Flight Center (MSFC) was tasked with characterizing the formation and evolution of liquid droplets resulting from nonlinear propellant slosh in a storage tank. Lateral excitation of propellant tanks can produce high amplitude nonlinear slosh waves through large amplitude excitations and or excitation frequencies near a resonance frequency of the tank. The high amplitude slosh waves become breaking waves upon attaining a certain amplitude or encountering a contracting geometry such as the upper dome section of a spherical tank. Inherent perturbations in the thinning regions of breaking waves result in alternating regions of high and low pressure within the fluid. Droplets form once the force from the local pressure differential becomes larger than the force maintaining the fluid interface shape due to surface tension. Droplets released from breaking waves in a pressurized tank may lead to ullage collapse given the appropriate conditions due to the increased liquid surface area and thus heat transfer between the fluids. The goal of this project is to create an engineering model that describes droplet formation as a function of propellant slosh for use in the evaluation of ullage collapse during a sloshing event. The Volume of Fluid (VOF) model in the production level Computational Fluid Dynamics (CFD) code Loci-Stream was used to predict droplet formation from breaking waves with realistic surface tension characteristics. Various excitation frequencies and amplitudes were investigated at multiple fill levels for a single storage tank to create the engineering model of droplet formation from lateral propellant slosh.